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Design and Implement of a Framework for a Hybrid Broadcast System using Voronoi Diagram for NN Search

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Abstract

The portable mobile devices with high performance and high speed 5G network activate and explode the demands for ubiquitous information services that remove the limitations of time for the communication and places to request for the information. NN (Nearest Neighbor) search is one of the most important types of queries to be processed efficiently in the information services. Various indexes have been proposed to support efficient NN search in the wireless broadcast system. The indexes adopting Hilbert curve, grid partition or Voronoi diagram enable the clients to search for NN quickly in the wireless broadcast channel. It is necessary that an efficient means to evaluate the performances of various indexes. In this paper, we propose an open framework that can adopt a variety of indexing schemes and evaluate and compare the performances of them. The proposed framework is organized with open and flexible structure that can adopt hybrid indexing schemes extensible to Voronoi diagram as well as simple indexing schemes. With the implemented framework, we demonstrate the efficiency and scalability and flexibility of the proposed framework by evaluating various indexing schemes for NN query.

Keywords: *Framework, NN search, Wireless data broadcast, Index.*

1. Introduction

Recently, portable mobile devices with high performance like smartphones activate and explode the demands for ubiquitous information services [1]. High speed 5G network and short-range communications such as Bluetooth and WiFi satisfy the demands by removing the limitations of time for the communication and places to request for the information [2]. In the environment, the clients access the information through various type of queries such as window query. Among the types of queries, NN (Nearest Neighbor) query is one of type to be issued most frequently and to be processed efficiently.

The quality of information services is required for the measures to ensure that the information services are seamless although the number of clients surges. The wireless data broadcast is an efficient way satisfying the requirements for the rapid increase of the number of clients in ubiquitous information services [3, 4, 5].

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Especially, the system enables the clients to access the data items for various types of queries. The broadcast server disseminates the data items on the wireless channel and the clients access the channel and filter out the data items that is the result of their queries. In the system, the server broadcasts an index to hold the time information when the data items appear on the channel. The index supports the clients to access more efficiently the data items they want.

A hybrid index of Voronoi and grid parttition helps the clients to process and filter out NN from the wireless channel. The index uses grid partitions for selecting the Voronoi segment that associated with a given query point for NN search. The selected Voronoi segemt contains the data item that is NN to the given query point. It is important to design and implement the framework to evaluate the performance of the hybrid index with Voronoi and grid partitions.

In this paper, we design a framework that enables to adopt the hybrid index scheme as well as simple indexing shemes and implement the framework. The implemented framework is so pliant and open that a variety of indexing schemes can be adopted and be evaluated for the performances.

This paper is configured as follows. In Section 2 Voronoi and hybrid index is reviewed as a related works. Section 3 describes the design of the broadcating server and the mobile clients of the framework. In Section 4, we implement the designed framework and evaluate the framework adopting the hybid index. Also, we compare the hybrid index and other existing index schemes for the performance parameters using the implemented framework. Finally, Section 5 makes conclusion.

2. Related Works

2.1 Voronoi Diagram

Voronoi diagram is the effective way to find the NN to a given query point [6]. The diagram partitions a data plane with polygons that contain only one data item. Each polygon guarantees that the data item in the polygons is the NN to an arbitary point in the polygon because the polygons are divided from the data plane for satisfying the condition that each polygon is a set of the closest point to data item. For example, Figure 1 shows Voronoi diagram for 7 data items. The NN to the query point P_q is D_2 because any point in polygon V_2 is closest to D_2 among 7 data items in the data plane. Thus, Voronoi diagram is the simple way to find NN to a given point. With Voronoi diagram, NN search turns into a domain inclusion problem.

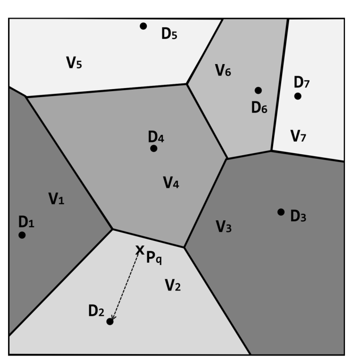


Figure 1. Voronoi diagram for 7 data items and grid

2.2 Index Schemes for Searching NN

In the wireless data broadcasting environment, a variety of indexes have been developed and applied to improve the performances. Using the index providing the time information when the data items appear to the channel, the clients can download selectively only data items to be queried from the wirless channel instead of listening to the channel continuously.

HCI (Hilbert Curve Index) is an index of B+ tree that uses Hibert curve for mapping the location of an item to an integer [7]. HCI is replicated m times in a broadcast cycle on the wireless channel to reduce the access time of the clients. Using HCI, the clients determine the search space and prune NN with the Hilbert curve integer. HCI provides the clients simple way to treat the locations with integers, but it makes the search space for NN is so large that the clients consume long time for downloading NN.

DSI (Distributed Spatial Index) uses Hibert curve as HCI. However, it adopts a distributed schem for allocating the index on the channel [8]. For following the distbiuted scheme, DSI is organized in a table with integers and the broadcasting time of data items. DSI allows the client to access NN more quickly than HCI by adopting the distributed scheme. However, DSI cannot avoid the problem that the search space for NN is large because of using Hilber curve integers for the locations of data items instead of real locations.

NSPI (Non-uniform Space Partition Index) is the index based on the grid partition with two-level structure [9]. NSPI uses real locations unlike HCI and DSI so that the clients can determine the search space for NN smaller than DSI and HCI. The upper-level index holds the distribution of entire data and thel lower-level index holds the time when the data items are broadcast on the channel. Using NSPI, the clients determine the search space for NN with the upper-level index and then prune NN from the search space with the lower-level index.

HIVG (Hybrid Index of Voronoi and Grid Partition) provides the clients a simple way to determine the search space for NN using Voronoi diagram and grid partition [10]. As shown in Figure 2, HIVG overlaps the grid partition with Voronoi diagram of data items. Using the grid partition, the clients decide the search space for NN, i.e., the candidate polygons for NN. Then the clients filter out the polygon containing NN with Voronoi diagram. For exmple, the search space for NN to the given query point P_q in Figure 2 is the three polygons of Voronoi diagram that are overlapped with the grid cell G_5 containing the given query point. The clients decide the polygon that contains the query point among the three polygons and filter out the data item of the polygon as NN to the given query point. Thus, HIVG provides the clients with the simple way to search for NN in the wireless data broadcast environment.

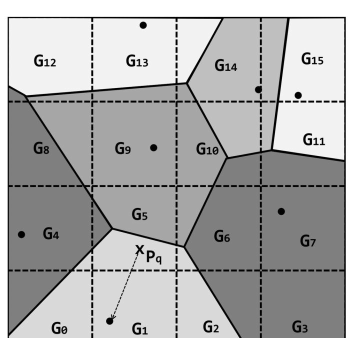


Figure 2. Grid over Voronoi diagram

3. Design of Framework for Voronoi Hybrid Broadcast System

We design the broadcast server adopting Hybrid Index of Voronoi and Grid Partition to support the clients to search for NN. Also, we design the mobile client to process NN queries on the wireless data broadcast environment.

3.1 Design of Voronoi Hybrid Broadcast Server

The broadcasting server supporting NN query processing is designed to be organized with the structure shown in Figure 3.

- Broadcast Manager: this component is in charge of managing the overall processes for broadcasting. It requests for organizing the wireless broadcast channel and requests for broadcasting to the transmitter.
- Channel Organizer: this module in the broadcast manager takes charge of allocating the data items and index information on the channel.
- Data Allocator: this component is in charge of allocating the data items to be broadcast which is returned from data repository.
- Index Generator: this component generates the Voronoi hybrid index with the Voronoi diagram and the grid partition. It requests for the diagram and partition to Voronoi Generator and Grid Generator.
- Voronoi Generator: this component generates Voronoi diagram using the locations of data items transferred from the Index Generator.
- Grid Generator: this component takes charge of generating the grid partition for the hybrid index using the number of grid cells from the Index Generator.
- Data Repository: this is a database which manages spatial data items. The repository responses to the requests from the Data Allocator and Index Generator.

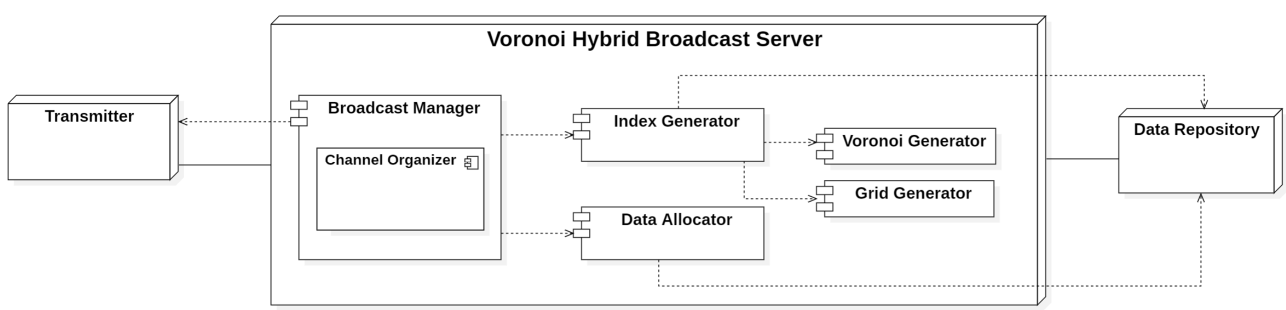


Figure 3. The component diagram of the broadcast server

The broadcast server in Figure 3 organizes the content for the wireless broadcast channel through the broadcast manager and broadcast the content via the transmitter. The server follows the process to broadcast data items and index information which is shown in the sequence diagram of Figure 4.

1, 2: The server triggers the broacast manager to organize the wireless channel. The broadcast manager requests the channel organizer for configuring the channel and then the channel organizer calls the index generator for the index information.

3, 4: The index generator demands first the information about the data items to the data repository and receives the information from the repository.

5, 6: The index generator requests for Voronoi diagram to the Voronoi generator with the information from the repository and receives the diagram.

7, 8, 9, 10: The index generator requests for the grid partition to the grid generator and receives the information about the generated grid. Then, the index generator configures the hybrid index for the broadcast and returns the index to the channel organizer.

11: The channel organizer needs scheduled data items to be broadcast so the organizer requests for data allocation to the data allocator.

12, 13, 14, 15: The data allocator demands the data items to be broadcast to the data repository. Then the repository sends the data items and the allocator arranges the items in order to be broadcast and returns them to the channel organizer.

16, 17: The channel organizer arranges the index from the index generator and the scheduled data items from the data allocator into the order to be broacast.

18, 19: The broadcast manager requests for broadcasting the organized channel contents to the transmitter. Then the transmitter broadcasts the organized channel contents from the broadcast manager.

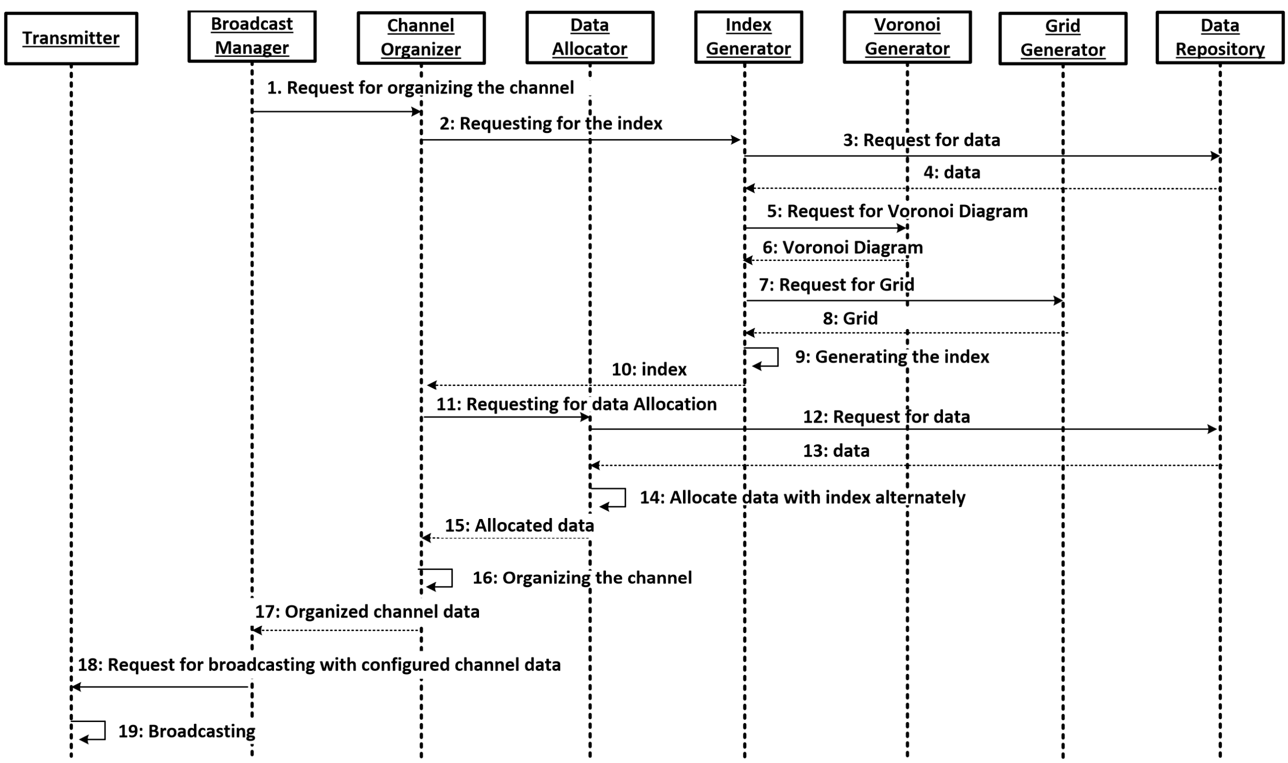


Figure 4. The sequence diagram for broadcasting hybrid index and data items

3.2 Design of Client and Search for NN

The mobile client to search NN to a given query point is designed with the structure shown in Figure 5.

- NN Query Processor: this component is in charge of managing the overall processes to search for NN to a given query point. It requests for downloading the index and data items to the channel listener and for analyzing the index to the index analyzer.
- Index Analyzer: this component takes charge of analyzing the index and extracting the broadcasting time for the NN to a give query point.
- Grid Extractor: this component is in charge of determining the grid cell containing the given query point.

- Voronoi Extractor: this component is in charge of determining the Voronoi segment containing the given query point amont the Voronoi segments associated with the grid cell.

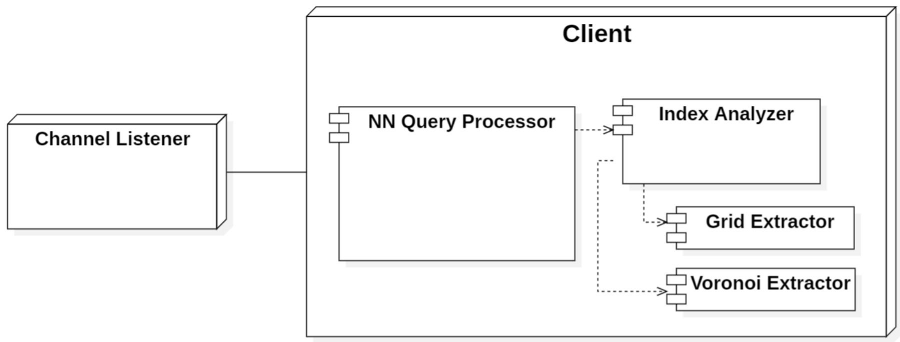


Figure 5. The component diagram of the client

The mobile client in Figure 5 follows the process to search NN to a given query point shown in the sequence diagram of Figure 6.

1: The user triggers the search for NN to a given query point by requesting for NN with the query point to the NN query processor.
2: The NN query processor demands the broadcasting time for NN to the index analyzer.
3, 4, 5: The index analyzer sends the request for downloading the index to the channel listener. The channel listener returns the index after downloading the index from the wireless channel.
6, 7: The index analyzer demands for extracting the grid cell containing the query point to the grid extractor. The extractor returns the grid cell which has the query point within itself.
8, 9: The index analyzer demands for extracting the Voronoi segment among the segments overlapped with the grid cell that containing the query point.
10, 11: The index analyzer determines the time when the NN appears on the channel and returns the time to the NN query processor.
12, 13, 14: The NN query processor requests for downloading the NN from the wireless broadcast channel to the channel listener. The listener returns the NN to the given query point to the NN query processor after downloading the NN at the determined time.
15: The NN query processor lets the user confirm the result to the NN query by displaying the NN.

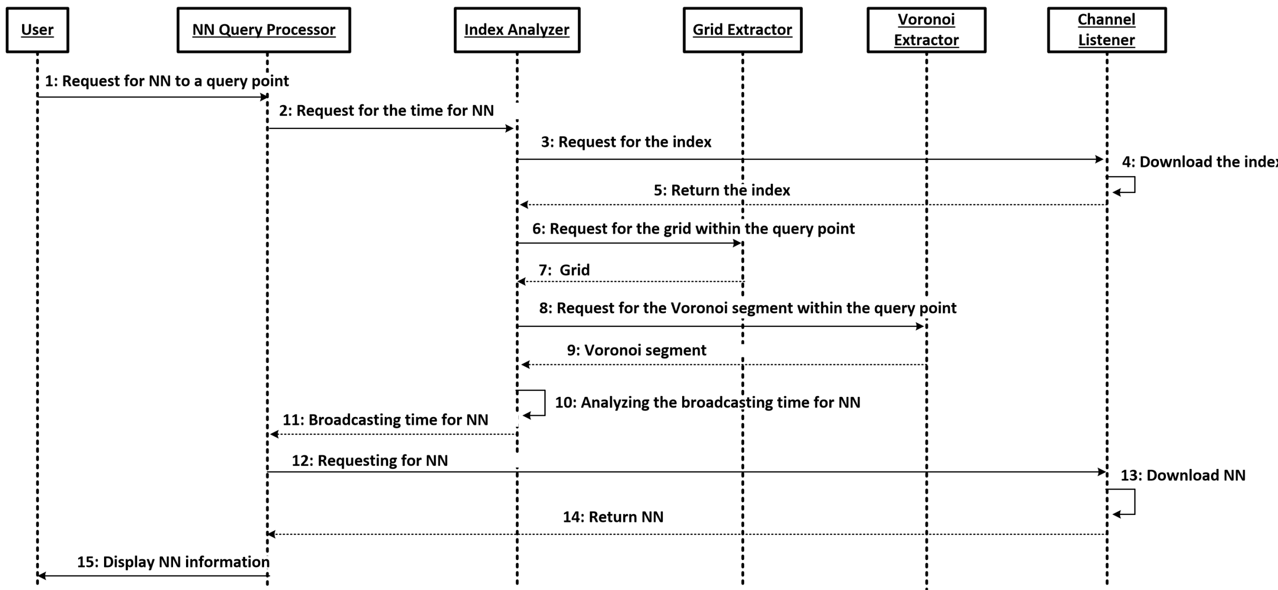


Figure 6. The sequence diagram for searching for NN on the hybrid broadcasting

4. Implementation and Experiments

We develop the framework by implementing the designed broadcast server and the mobile client that are structured with the components in Figure 3 and Figure 5. The server and the mobile client follow the process for broadcasting and searching for NN that are shown in Figure 4 and Figure 6, respectively. We implement the framework usin SimJava, a simulation scheduler in the discrete time. Through the implemented framework, we run simulations for processing NN searching on the wireless data broadcast environment.

Figure 7 shows the user interface for the implemented framework. The interface shows the access time and the tuning time that are two main performance parameters of wireless data broadcast. The two parameters enable to evaluate how effective the broadcast system is. The LOAD DATA button makes possible to select and load data items for wireless data broadcasting and SIM SETTINGs button to set the simulation conditions in detail. The RUN button triggers the simulation with the simulation condition set by the SIM SETTINGS.

For the simulation, we adopt 10258 American shopping sites as the data set with a real distribution. To show the effectiveness of the implemented framework, we evaluate the hybrid Voronoi index by comparing the performance parameters with other indexing schemes NSPI, DSI and HCI. For the simulation we assign the id of grid cells to 8 bytes, an apex of the Voronoi segment to 8 byes, the data size to 2048 bytes, and the size of bucket to 128 bytes. For comparing the performances, the client runs 100,000 NN queries with the simulation conditions.

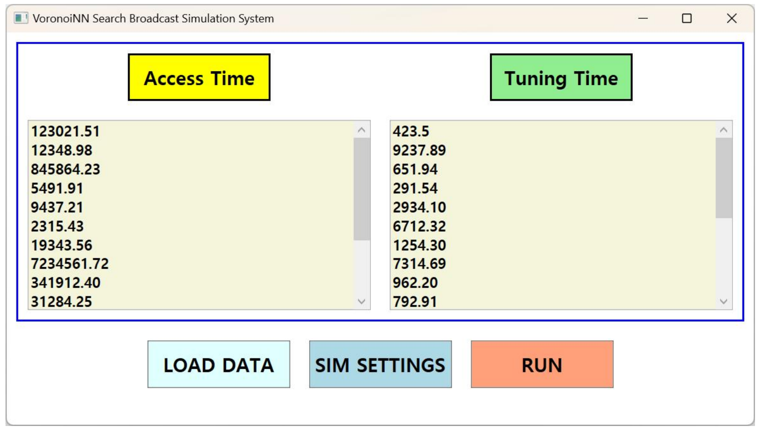
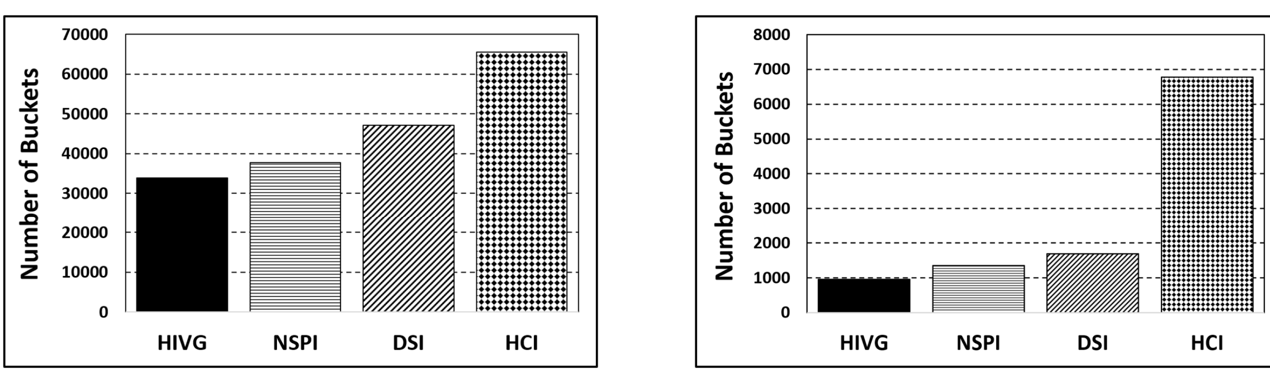


Figure 7. The interface of simulation framework for hybrid broadcasting system

Figure 8(a) depicts the average access time according to the indexing schemes. HIVG allows the clients to access NN more quickly than other indexing schemes. This result demonstrates HIVG is more efficient to determine the NN to a given query point that NSPI, DSI and HCI. Also, the result shows the effectiveness of the implemented simulation framework. Figure 8(b) depicts the average tuning time by the indexing schemes. HIVG consumes more shorter energy than other indexing schemes because the tuning time means the energy consumption of the client during the process of the NN query. Thus, the implemented framework is effective to show the efficiency of the Voronoi hybrid broadcasting system which adopts HIVG. Also, the framework enables to adopt other indexes designed using Voronoi hybrid schemes as well as HIVG. That shows the framework is so pliant and open that other indexing schemes can be adopted and be evaluated for the performances.



(a) The access time **(b) The tuning time**

Figure 8. The comparison of the performances by the implemented framework

5. Conclusion

We proposed and implemented the framework for evaluating hybrid broadcasting system that can adopt various indexing schemes and be extensible to hybrid indexing schemes using Voronoi diagram for NN search. The framework is configured with the Voronoi hybrid broadcasting server, the mobile clients to search for NN to a given query point. The server is structured with components, broadcast manager, channel organizer, data allocator, index generator, Voronoi generator and grid generator. The client is configured with NN query processor, index analyzer, grid extractor, and Voronoi extractor. The framework enables to adopt and evaluate HIVG using Voronoi diagram, NSPI using grid partition, HCI as well as DSI. We show the effectiveness of the framework by comparing the performances of various indexing schemes adopted to the wireless data broadcasting system. That shows the framework is so flexible and open that simple indexing schemes as well as hybrid schemes can be adopted and be evaluated for the performances. For simulating with the framework, we use American shopping sites with real distribution and compare the access time and the tuning time of the indexes, HIVG, NSPI, DSI, and HCI. The simulation results depict the implemented framework enables to disseminate effectively using the Voronoi hybrid wireless data broadcasting system and supports the large number of clients to process NN queries to given query points.

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